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Silver coelacanths from Spain are not proofs of a pre-scientific discovery

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In 1964 and 1965, two silver fish pendants depicting coelacanths and thought to be religious votive from Spanish churches were purchased on the art market in Spain, dated between the 17th and late 19th century, long before the discovery for science of the living coelacanth in 1938. It was speculated that they originated either from the Mediterranean, subtropical Atlantic, or subtropical Pacific (de Sylva 1966, Bruton 1985, Anonymous 1993, Greenwell 1994, Raynold & Mangiacopra 1995). Some authors believe that the silver fish pendants represent a new species of coelacanthiforms (Raynold & Mangiacopra 1995), others claimed the pendants to be only a wishful fantasy of scientists and not coelacanths at all (Thomson 1991). However, new studies revealed that the silver fish artefacts are indeed coelacanths but were in fact produced more recently with the Comorian coelacanth, *Latimeria chalumnae*, as a model.

The 1964 artefact was purchased by the Argentinian chemist, Dr. L. Reti, but could not be traced further and must be considered lost. It was reported that Reti obtained the silver fish pendant from a priest near Bilbao on the Atlantic coast of Spain (de Sylva 1966, Bell 1967). The 1965 artefact is in the possession of Prof. M. Steinert, Brussels, who purchased it in an art gallery in Toledo, near Madrid (Anthony 1976).

The 1964 artefact, an articulated pendant about 10 cm long, matches the slender body shape of the original 1938 coelacanth holotype, in particular the shape of the head with the insertion of the pectoral fins behind the gill covers (Figures 1a,b). The head can be flipped downwards via a small hinge located ventrally. Unfortunately, Reti's photograph was cut so that the epicaudal lobe of the artefact cannot be seen. While the unpaired second dorsal and anal fins match perfectly the holotype, the position of the paired fins in relation to the first dorsal fin is inaccurate. This has probably mechanical reasons. The artefact stands on its anal and both paired fins. If the pectoral fins were positioned as in the real fish, they could not be used as a support. Furthermore, the taxidermists who prepared the holotype had bent the paired fins into an unnatural downward position to produce an 'Old Fourleg's' appearance (Figure 1b) that has not been observed in real animals (Fricke et al. 1987). The 1964 artefact reveals this unnatural fin position and depicts even some details of the damaged caudal fin of the holotype. All this evidence suggests that it is indeed a coelacanth and that it was produced using the holotype as a model.

The 1965 pendant is 35 cm long and has body parts articulated by a complicated system of joints. The positions of its paired and unpaired fins do not match the fin insertions of the real fish. The pectorals should be closer to the gill covers. Some patterns of engraving on the body of this fish pendant seem to represent the white spots found on the real fish. Due to tissue deterioration and fixation white spots were not described on the 1938 specimen (Smith 1939); they were first mentioned in publications and shown on photographs of the early fifties (e.g., Millot 1954). The pendant was,

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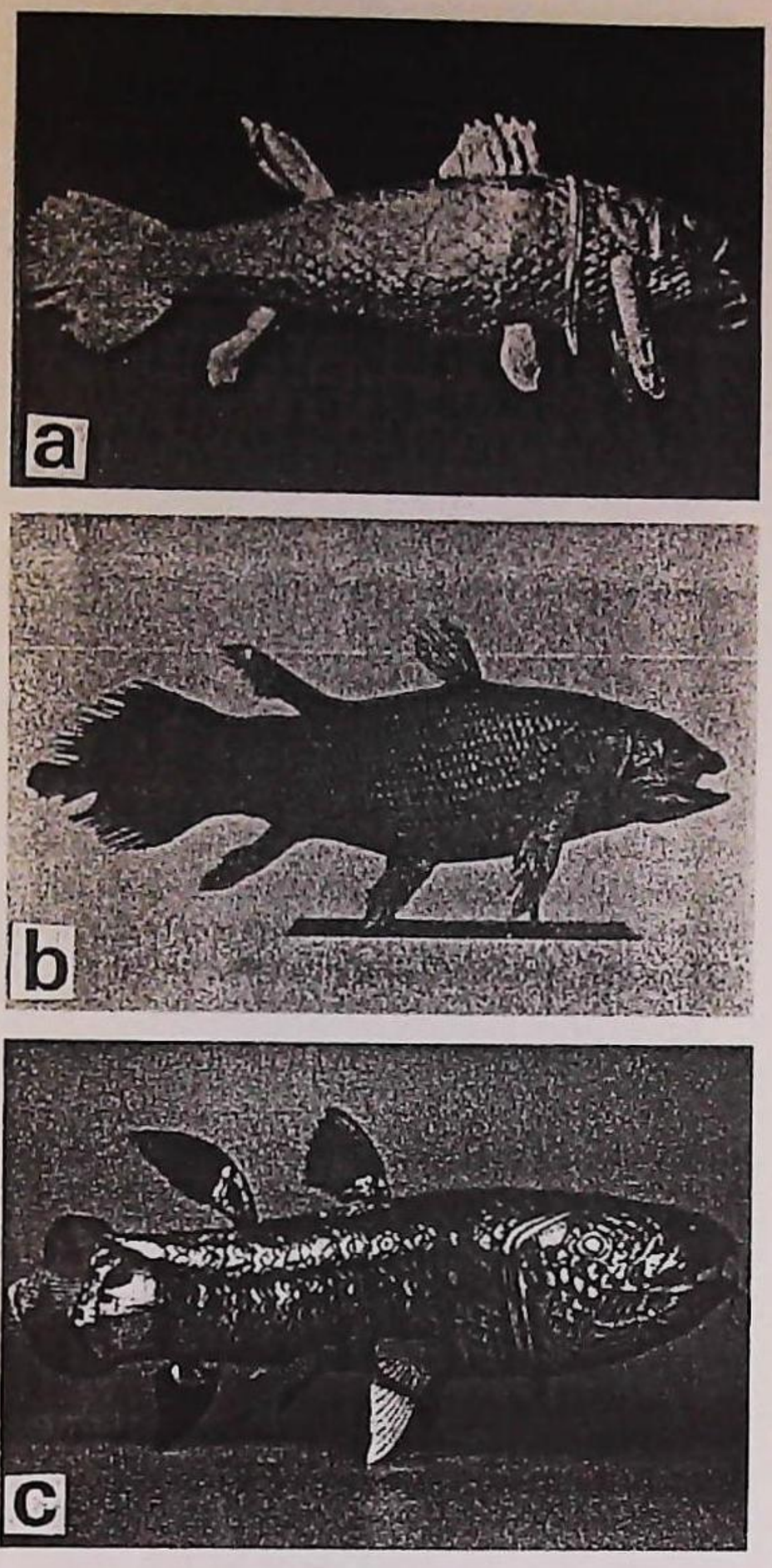

Figure 1. a – the 1964 coelacanth artefact of Bilbao, Spain (from de Sylva 1966); b – the holotype from 1938 displayed in the Natural History Museum in East London, South Africa, c – the 1965 coelacanth pendant of Toledo, Spain.

therefore, most likely created between 1954 and the date of purchase in 1965 (Fricke 1989).

In May 2000 the world authority on Spanish silver art, Prof. Cruz-Valdovinos (Departamento de Arte Contemporaneo, Universidad de Madrid) studied the 1965 pendant. He agreed on the provenance, the fine handmade artwork, and the old appearance of the fish pendant. He did not think, however, that this pendant was used as a votive (or ex-voto) because silver fish artefacts are generally not used as ex-votos in Spanish churches. This argument had also been put forward to us by Padre Valverde, director of the Museo Episcopal de Bilbao. Furthermore, the anatomical detail of the 1965 piece is – according to Cruz-Valdovinos – extremely unusual and not known from any other Spanish silver work. This artefact lacks style marks, such as peculiar fantasy engravings, typical for baroque silver art pieces of the 16th or 17th century. In Spanish folklore art fishes are rarely depicted naturalistically because this would decrease their appeal and reduce their value on the art market. The sharp edges of all fins, teeth, scales, and on the surface of pectoral and pelvic fins are similar to modern Spanish folklore art. Sharp edges suggest also a recent origin since otherwise the body surface and edges of old art pieces are unavoidably smoothed by handling.

In 1965 M. Steinert had taken photos from other silver fish displayed together with the silver coelacanth in the art gallery. Cruz-Valdovinos examined the photos and concluded that all silver fish artefacts originated from the same silversmith or an identical art school. It is very unlikely that such a collection would have remained undispersed over centuries. A further argument for modern origin of the 1965 piece is its low purchase price. Taking into account the price of silver and the effort to produce such a detailed pendant, the object seems substantially underpriced even for a modern art piece. A genuine antiquity would be far more expensive.

Cruz-Valdovinos believe that the silver coelacanth was very likely produced using photographs as models. This opinion is supported by the fact that the ventral head structure, which is not visible on the published photographs, is imprecise and lacks the gular bones that are obvious and diagnostic of coelacanths (Figure 2).

In May 2000, A. Jimenez, an expert of silver artefacts in Madrid and a specialist in the fabrication of silver fishes, inspected the 1965 artefact independently of Cruz-Valdovinos. He identified it as a typical Spanish folklore art piece and excluded its Meso-American origin. After a thorough study of the body surface, colour, mechanics of the hinge connecting the head and body, and details of the body carvings, he estimated the age of the artefact between 30 and 50 years, which agrees with the earlier estimated creation between 1954 and 1965. A. Jimenez also noted the great beauty and the unusually low price of the artefact. According to his opinion the 1965 artefact (and also very likely the 1964 silver coelacanth) was not used as a marine ex-voto

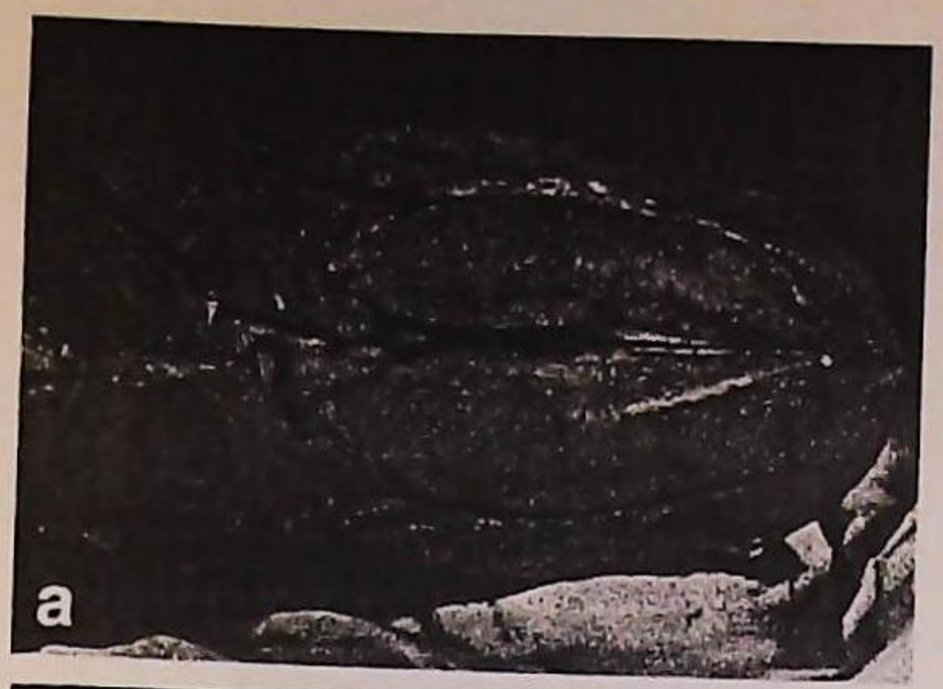

Figure 2. Ventral view of the head of a coelacanth: a – with conspicuous gular bones (from Millot 1954), b – fantasy engravings on the 1965 pendant instead of the gular bones.

in churches but merely as a decorative ornamental piece.

In the past all speculations about the antiquity of the silver coelacanths were based on photographs. Earlier in 1989, when examining photographs of the 1965 artefact, Cruz-Valdovinos suggested a 16th or 17th century date of origin for the art piece (Fricke 1997), but he warned at the same time that a firm conclusion cannot be drawn from a study of photographs; silver art experts have to handle the objects to be certain. This was not done until May 2000. The new evidence would suggest that the silver coelacanths from Spain neither are a proof of a pre scientific discovery of living coelacanths before 1938 nor do they hint at the existence of a new species or a new distribution outside the Comoros.

Acknowledgements

We thank Maurice Steinert for lending us his silver coelacanth in order to put it into the hands of silver experts. We are most grateful to Jose Cruz-Valdovinus and Antonio Jimenez for generously giving their time and expertise, to Carlos Mamblona from Munich who kindly translated the interviews, and to Gene Helfman and Christine Flegler-Balon who corrected the English; Arthur Myrberg helped with literature, Heidrun Bamberg and Theo Weber prepared the figures.

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An account of the first living coelacanth known to scientists from Indonesian waters

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Synopsis

A brief narrative is presented of the events surrounding the initial discovery of a coelacanth in an Indonesian fish market in Manado, Sulawesi, on 18 September 1997. Although the specimen was not purchased and preserved, photographs were taken and enough information gathered about the fish to warrant an official entry in the Coelacanth Conservation Council (CCC) inventory of known specimens of the living coelacanth *Latimeria chalumnae*. All known information about this first Indonesian specimen is summarized in the official CCC inventory format, and the specimen is herein numbered CCC no. 174.

Introduction

As first reported in Erdmann et al. (1998), the initial discovery of a coelacanth specimen in a North Sulawesi, Indonesia fish market on 18 September 1997, and the subsequent capture and preservation of a second specimen from the same area on 30 July 1998 strongly suggest the existence of a Sulawesi population of living coelacanths. A preliminary morphological examination of the second specimen indicates that this population is likely of the same species as the well-known Comoran population of coelacanths, *Latimeria chalumnae* Smith, 1939. Ongoing genetic analyses should help confirm if this is indeed the case.

Since the initial announcement of the Indonesian coelacanths, the story of the events surrounding the discovery has been rewritten and retold in numerous television and radio programs and newspapers and magazines the world over. Unfortunately, the overwhelming majority of these accounts have contained substantial factual errors. It is the intention of this account to accurately record the sequence of events on 18 September 1997 and the days immediately following the initial sighting, as well as to document specific details of the first reported Indonesian specimen.

While the personal narrative which follows is perhaps atypical for scientific papers, the continuing saga of the living coelacanth has always been one in which the human details are intimately intertwined. It is also interesting to note that the events in this sixty-year saga have been continuously revised in subsequent accounts by various authors. Marjorie Courtenay-Latimer, the discoverer of the first coelacanth trawled off South Africa in 1938, waited fifty years to publish her own account of the find (Courtenay-Latimer 1989) and thereby lay to rest all of the previous stories, many of which differed significantly from her own. It is the goal of this account to promptly establish the proper chronology of events of this discovery.

The first Indonesian coelacanth

On the morning of 18 September 1997, the author and his newlywed wife, Arnaz, escorted their friends John

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and Janel Intihar to the Pasar Bersehati fish market in Manado, North Sulawesi. John and Janel, who had recently attended our wedding in Bali and subsequent honeymoon cruise around the islands of Komodo, had extended their stay in Indonesia in order to accompany us to north Sulawesi, where I was preparing to begin a two-year postdoctoral research project in coral reef ecology. On the last day of their stay, we suggested a tour of the local fish and produce market, one of our favorite activities whenever we visit a new Indonesian city.

As we stepped out of the taxi at the market, Arnaz's attention was immediately drawn to a large fish on a cart being wheeled across the parking lot by an elderly gentlemen. She called the three of us over, puzzled by the identity of this fish. I immediately recognized it as a coelacanth, having read the story of 'Old Fourlegs' with fascination as a schoolchild. Although I was aware that as of my school days, the coelacanth had not been reported outside of the western Indian Ocean, I had not followed the literature since that time and felt that our 'discovery' was a bit too fortuitous to be real. I simply couldn't believe that we were viewing something which was unknown to science, having just stepped out of a taxi at a bustling market in a relatively large city. Surely the coelacanth must have been previously reported from Indonesia?

Nonetheless, I borrowed Janel's camera and snapped three photographs of the fish (Figures 1a,b), and Arnaz began asking the old fisherman questions about its capture. He had broken Indonesian (his native tongue was the Siau language), and seemed relatively uncomfortable talking about the fish. By this time a crowd was gathering around us, and many offered the advice that this was a grouper. When we asked the old man where he had caught the fish, he simply replied 'dasar laut' (meaning 'sea floor'). Upon further questioning, he explained that the fish was caught at night in approximately 100–200 m depth. When asked where the fish was caught, he turned and pointed out to sea in the general direction of the islands outside of Manado Bay. We then asked if he caught many of these fish, and he replied 'jarang' (infrequently), but then added that he had caught several over his lifetime.

By this point the fisherman was clearly becoming uncomfortable with all of the attention bestowed upon him, and was eager to push his fish cart out of the hot sun. I agonized over whether to try to buy the fish, but wavered and eventually decided against it. Surely this was not a big discovery, and besides, where would we keep such a large specimen while staying in a small hotel? I further reasoned that since we would be working in this area for the next two years, there would be plenty of opportunity to collect another specimen should this later prove to be an important find. I was to regret that decision for almost a year.

Shortly thereafter, we returned to the U.S. for a short visit, both to resupply and to attend John and Janel Intihar's wedding. During the long airplane ride home from Indonesia, I had mused at length about our possible course of action should the Indonesian coelacanth prove to be new to science. Immediately upon arrival in Berkeley, I approached my colleague and former Ph.D. advisor, Roy Caldwell, to ask him if he knew of coelacanths reported from outside of the Comoros. He replied that he did not know of any such reports, and a quick glance through his library convinced us that this was indeed an exciting discovery. We agreed that we would pursue this discovery further upon my return from John and Janel's wedding.

In the meantime, John and Janel had returned to the U.S. as well, and had constructed a world wide web site featuring pictures from our wedding and honeymoon cruise. One of the picture collages they created was devoted to photographs taken in Manado, and included all three of the coelacanth pictures. John sent an e-mail announcement about the website to all of the wedding guests, including Roy, shortly after we arrived in the states and had told Roy of the find. Roy had browsed the web site, and excitedly told several other Berkeley professors of the coelacanth pictures. One of these professors was George Barlow, who immediately realized the importance of the find and e-mailed his former student, David Noakes at the University of Guelph in Ontario.

David hurriedly contacted Roy to inform him that while this was a very important find, it was imperative that this not be made public until properly documented and especially until preventative measures were taken to protect the Indonesian population of coelacanths. Both he and Eugene Balon, the Guelph coelacanth specialist, were very concerned that the website publicity would spread quickly and that soon thereafter

Figures 1a,b. The first known Indonesian coelacanth, discovered at the Pasar Bersehati fish market in Manado, north Sulawesi on 18 September 1997. The specimen was later sold.

collectors would be combing Manado for further specimens, dead or alive. David and Roy managed to contact me enroute to John's wedding, and we were also able to speak with John and had him remove the photographs from the website, all within hours of Roy's initial viewing!

Shortly after the Intihar's wedding, I returned to north Sulawesi to begin the search for a second specimen. Roy and I obtained additional funding from the National Geographic Society to support fishermen interviews throughout north Sulawesi, and the search began in earnest. After five months of visiting fishing villages around the province, I eventually located the elderly fisherman who had been wheeling the first specimen across the market on that fateful day. Only then did we learn that it was actually his son, Om Maxon Haniko, who had captured the specimen in a deeply-set shark gillnet off of the volcanic island of Manado Tua. We subsequently identified a second shark net fisherman from the same island, Om Lameh Sonatham, who had also captured coelacanths in the past. Four months later, Om Lameh brought to us the second specimen, and this time the fish did not get away. Details of the second specimen are presented in the next rapid communication (Erdmann et al. 1999).

CCC entry

All relevant data known about the first Sulawesi specimen are summarized below. This data entry follows the structure of the official Coelacanth Conservation Council (CCC) inventory of all known specimens of the coelacanth *Latimeria chalumnae* (Bruton & Coutouvidis 1991).

(1) *CCC no. 174.*

(2) *Date and time of capture:* 18 September 1997, before dawn. The gillnet in which the specimen was captured was set at 18:00 h on the previous day, and pulled from the water at 6:30 h on 18 September. The sea was calm during this time, and the lunar phase was two days past the full moon.

(3) *Site of capture*: Directly offshore from the village of Kampung Negeri, Manado Tua island. Latitude/longitude: 1°37′N, 124°43′E.

(4) *Name of fisherman*: Om Maxon Haniko, 36 years of age, was the head of the shark net crew which captured the fish.

(5) *Distance from shore at capture*: Approximately 200–300 m from shore. The shallow (1–3 m) reef flat here is approximately 150 m wide, ending in an abrupt dropoff to 40 m depth, followed by a steep slope to well over 200 m. The shark net is anchored at the edge of the dropoff with a long rope, and the net itself extends up to 150 m from the dropoff.

(6) *Depth of capture*: Approximately 100–200 m. As the net itself is 150 m long, and extends downwards along the reef slope, it is difficult to make an approximation of the depth of capture.

(7) *Bait used*: No bait was used. As mentioned above, this specimen was captured with a deep-set shark gillnet. Dimensions of the net are as follows: 150 m in length, 11 m in height, mesh size of 6 cm square (unstretched). The net is anchored to the top of the reef flat by a 200 m long thick rope, and the net is set 3.5 m above the substrate, using buoys along the top of the net and heavy stones on the end of 3.5 m long ropes attached to the bottom of the net. The net is set in the late afternoon (17:00–18:00 h), left in place overnight, and hauled in at dawn the next morning.

(8) *Weight*: The specimen weighed approximately 30 kg.

(9) *Length*: Approximately 1.3 m TL.

(10) *Sex*: Undetermined.

(11) *Condition on capture*: This fish was still alive when the net was hauled in, and reportedly remained alive for several hours after landing.

(12) *Method of preservation*: As described above, this specimen was unfortunately not purchased and preserved. It was later purchased by an unknown citizen of Manado for 30 000 Indonesian rupiah (approximately US$ 12.00 at the time).

(13) *Condition of preserved specimen*: Not applicable.

(14) *First literature reference*: Erdmann et al. (1998).

(15) *Current holding*: Not applicable.

(16) *Additional comments:* While it is certainly unfortunate that this first Sulawesi specimen was not preserved for science, this does not diminish the excitement and importance of this find. The fact that living coelacanths could escape detection from the scientific community in an area well-studied by ichthyologists for over 100 years is wonderful; it is a humbling and exciting reminder that humans have by no means conquered the oceans, and provides hope that 'Old Fourlegs' is more abundant and resilient than we initially dared hope.

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Are the Indonesian and western Indian Ocean coelacanths conspecific: a prediction

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Synopsis

It is hypothesized that the ancestor of the extant western Indian Ocean and Indonesian populations of *Latimeria* was continuously distributed along the deeper coasts of massed Africa–Madagascar–Eurasia in early geologic time. The collision of India with Eurasia, roughly 50 MY ago, caused the formation of the Himalayan Mountains and subsequent developement of numerous rivers. The rivers, which flow down both coasts of India, and areas even further east, deposited, and continue to deposit, great amounts of silt along both coasts of India. The siltation destroyed possible coelacanth habitats, thus isolating coelacanth populations to the west of India from those to the east and allowing them to diverge.

Discussion

Coelacanths, presumably conspecific with *Latimeria chalumnae*, have been found recently (September 1997) to occur off Manado, Sulawesi, Indonesia (Erdmann et al. 1998). Previously, the species was believed to be restricted to the southwestern Indian Ocean, some 10 000 km west of Manado. Not in the 60 years since its first reported discovery in 1938, and the subsequent collection of an estimated 200+ specimens, has *L. chalumnae* been reported to occur naturally in waters other than those surrounding the Comoros Islands. Isolated captures off the coasts of Mozambique, southern Madagascar, and South Africa (ca. 800 km SW, 1200 km SE, and 2900 km SW from the Comoros) are considered to be strays transported by the strong prevailing ocean currents in the area (Schliewen et al. 1993). DNA comparisons (Schliewen et al. 1993) of the Mozambique and Comoros specimens indicate that the fish belonged to the same population.

Forey (1998) opined that the Comoro and Sulawesi populations of *Latimeria* are probably 'quite distinct', based on the distances separating them, the different geological histories of the two areas, and the direction of ocean currents in the region. He noted that DNA comparisons between Comoros and Indonesian specimens could test this possibility. If, however, it eventuates that the two populations are undifferentiated, he suggests that the species may be even more widely distributed than currently believed, and much more deeply occurring, thus enabling the species to transcend the great ocean depths necessary for it to have dispersed to Indonesia (or vice versa). I concur with Forey in predicting that molecular (and/or morphological) evidence will show that the two populations are distinct. The following discussion develops my reasons.

Information on reproductive mode, ecology, age, population structure, food, and behavior of the Indian Ocean population of *Latimeria chalumnae* have been summarized by Wourms et al. (1991), Bruton & Stobbs (1991), Bruton & Armstrong (1991), Fricke et al.

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(1991), Uyeno (1991), and Uyeno & Tsutsumi (1991). *Latimeria chalumnae* is a large (to 1.8 m total length), live bearer, producing 'enormous' eggs and relatively few (up 26; Bruton et al. 1992), large young, with a population size in the Comoros estimated to comprise fewer than 500 individuals.

The largest late-term embryo recorded is 358 mm total length (Bruton et al. 1992) and the smallest free-living specimen available, a neonate, is 420 mm; however, a native fisherman reported seeing a 250 mm specimen with completely resorbed yolksac swimming in apparent distress near the ocean's surface. The age attained by available specimens, based on scale readings, is either 11 or 22 years, depending on whether annuli are produced at the rate of one or two per year. Native fishermen in the Comoros have reported coelacanth catches from depths of 40–1000 m, but observations to depths over 300 m made from submersibles indicated that the species is limited to depths no greater than 253 m, which is roughly the depth limit of rocky caves in the area. Coelacanths are bottom or epibenthic drift feeders, that remain inactive in deep caves during the day, but ascend to shallower depths at night, apparently to feed. They appear to be slow swimmers, but capable of quick motions of short duration. They are confined mostly to waters with temperatures below 18°C, although water temperatures in the caves they entered approached 23°C.

The information recounted might be expected to be descriptive of a fish with a restricted distribution. A relatively large, deep-water, epibenthically associated, cave-dwelling fish without a planktonic larva, and with low fecundity and population density is an unlikely candidate for successful long-distance dispersal by currents. Bruton & Stobbs (1991), however, may be correct in suggesting that the distribution of coelacanth populations may be wider than just the Comoros in the western Indian Ocean. In this respect, they cite particularly the eastern coasts of Madagascar, northern Zululand, and the southeast coast of South Africa, which have deep rocky reefs and have not been explored with the appropriate fishing gear. If they are correct, the South African waif, noted earlier, could have well been a resident of that coast. Certainly, if the distribution patterns of shallow-dwelling (to ca. 30 m) shore fishes restricted to the western Indian Ocean are an indication, *Latimeria* is probably more widely distributed in the area than is currently indicated.

Gordon (1998) has taken issue with Forey's (1998) assertion that ocean currents in the Indian Ocean would support the distinctiveness of the Comoros and Indonesian coelacanths. As cited by Gordon, Gordon (1986), Gordon & Fine (1996) and Gordon et al. (1997) have shown that 'there is a direct flow of surface and thermocline (upper 400 m) water from the Mindanao Current . . . into the Sulawesi Sea. After transversing Makassar Strait this flow, called the Indonesian Throughflow, enters the Flores and Banda seas before spreading into Timor Sea and Indian Ocean. Once in the Indian Ocean the Indonesian water spreads westward . . . embedded within the South Equatorial Current along 12° S, eventually reaching the Comoran Islands.' Gordon concluded that coelacanth populations might exist along the route of this flow.

The average surface velocity of the westward flowing South Equatorial Current (SEC) is about 24 nautical miles per day (A.L. Gordon personal communication). At 10–15° S, it would take an object in the current about 175 ± 25 days to make the transit from 120° E, approximate longitude of entry of Indonesian flowthrough water into the Indian Ocean (Gordon & Fine 1996, Gordon et al. 1997) to 50° E, longitude of NE Madagascar, first major landfall of the SEC in the SW Indian Ocean. Christmas (106° E) and Cocos-Keeling (97° E) islands in the eastern Indian Ocean lie within the current and could possibly harbor coelacanths, thus decreasing the transit time. It seems doubtful, however, that a coelacanth caught in the SEC could make the transit to landfall in the western Indian Ocean in less than 100 days. That a bottom dwelling fish could prevail for 100 or more days in the open ocean is problematic.

Mauritius, Seychelles, and Maldive islands in the western Indian Ocean would seem to be likely candidates for harboring coelacanths, but because of heavy fishing in these areas and the presence of knowledgeable residents (variously including ichthyologists), if coelacanths existed in or strayed into these areas they would have been caught and recognized by now. The coasts of India are washed by silt-laden waters caused by the numerous rivers emptying along the coasts and, therefore, would not be expected to harbor coelacanths.

If the coelacanth populations in the western Indian Ocean and Indonesia prove recognizably different, as I predict, the geological history of the area, as Forey noted, but did not describe, may provide an explanation of how the divergence was initiated. For this, I propose the following abbreviated scenario.

At some earlier time, the ancestor of the present coelacanth populations must have had a more-or-less

continuous distribution that was interrupted later by a barrier. During the late Jurassic (ca. 140 Mya), just prior to the beginning of the breakup of the southern continents (Audley-Charles et al. 1981, figure 3.3), Africa, Madagascar, Antarctica, and Australia were united, and Africa was linked northwards with the Eurasian plate. The distribution of ancestral *Latimeria* was more-or-less continuous along the coasts of these massed continental blocks. India separated from Madagascar and began its move north in early Cretaceous (140–120 Mya; Audley-Charles et al. 1981, figure 3.4), possibly carrying coelacanths with it. Madagascar separated from Africa shortly thereafter, but its separation ceased by magnetic anomaly 2 (ca. 115 Mya; Besse & Courtillot 1988; however, Rabinowitz et al. 1983, propose that Madagascar began separating from Africa about 180 Mya and ceased at 120 Mya). India continued its 'flight' north and began colliding with the Eurasian plate in Eocene (40–50 Mya; Audley-Charles et al. 1981, figure 3.8). Continuous and still continuing movement of India into the Eurasian plate caused the building of the Himalayan Mountains, which resulted in the formation of many great rivers that flooded into the Indian Ocean down both coasts of India and the coast of Burma; e.g., the Indus, Ganges, and the Ayeyerwady (Irawaddy). The heavy siltation covered the bottom, both near shore and deeply offshore, and eliminated habitats suitable for *Latimeria*. India, thus formed a barrier between coelacanth populations to the east (Africa–Madagascar) and west (Malaysia–Indonesia; see color maps for 30 Mya in Hall 1997).

The isolation of the Comores and Indonesian coelacanth populations probably began several million years after the docking of India with Eurasia. The formation of the Himalayas and associated major river systems would have taken considerable time to develop. According to Gansser (1964) a major river system, forerunner of the Indus (and possibly the Ganges), was not developed until the Siwalik epoch (Middle Miocene, which would be about 15 Mya).

Hocutt (1987) first proposed that the movement of India north and its junction with the Eurasian plate was the vicariant event that explains a relatively high rate of endemism in marine organisms in the western Indian Ocean. Springer & Williams (1990) reported that many fishes and other marine organisms are represented by disjunct populations or sister groups in the Indian and Pacific oceans. Although these circumstances have been reported to apply only to shallow-dwelling organisms, and in the case of Springer & Williams (op. cit.), believed to be the product of glacial sea-level changes, the distribution patterns may apply to deeper-dwelling organisms as well.

In summary, I believe the collision of India with the Eurasian plate formed a barrier isolating the distributions of many marine organisms, including coelacanths, in the western Indian Ocean from those in the eastern Indian Ocean and/or Pacific Ocean, thus allowing the populations on either side of the barrier to diverge.

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The second recorded living coelacanth from north Sulawesi

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Synopsis

A detailed account of the second coelacanth specimen known to have been captured in Indonesian waters is provided. The account is written in the official format of the Coelacanth Conservation Council's (CCC) inventory of known specimens of the living coelacanth *Latimeria chalumnae*, and the specimen is herein numbered CCC no. 175. Morphological measurements and fin ray counts are recorded. A comparison of these measurements and meristic data with those recorded for Comoran specimens of *Latimeria chalumnae* shows that the present specimen has a similar allometry to *L. chalumnae*. Ongoing genetic analyses should reveal the depth of divergence between the two known populations of living coelacanths and help determine if this specimen is conspecific with its Comoran counterparts.

Introduction

As first reported in Erdmann et al. (1998) and Erdmann (1999), the initial discovery of a coelacanth specimen in a north Sulawesi, Indonesia fish market on 18 September 1997, and the subsequent capture and preservation of a second specimen from the same area on 30 July 1998, strongly suggest the existence of a Sulawesi population of living coelacanths. Those authors suggested that preliminary morphological examination of the second specimen indicated that the Sulawesi population is the same species as the well-known Comoran population of coelacanths, *Latimeria chalumnae* (Smith 1939).

The purpose of this paper is to record all relevant details of the second specimen within the established framework of the Coelacanth Conservation Council's (CCC) inventory of known specimens of *Latimeria chalumnae* (Bruton & Coutouvidis 1991). We also provide a comparison of selected morphological measurements and meristic data from this specimen to those reported for Comoran *L. chalumnae* by McAllister & Smith (1978). Details of the search for the second Sulawesi specimen, as well as a description of the potential habitat, the fishery which accidentally catches coelacanths, and the current conservation status of the Sulawesi population will be described in a future paper (Erdmann & Caldwell unpublished).

The second Indonesian coelacanth

Below we present the official CCC entry for the second Sulawesi coelacanth specimen, following the format of Bruton & Coutouvidis (1991).

(1) *CCC no. 175.*

(2) *Date and time of capture*: 30 July 1998, before dawn. The gillnet in which the specimen was captured was set at 17:30 h on the previous day, and pulled from the water at 6:00 h on 30 July. Calm seas, seven days after the new moon (first quarter).

Strictement réservé à l'usage privé
(Loi n° 57-298 du 11 3 57, art. 41,2°)

(3) *Site of capture*: Directly offshore from the village of Papindan, Manado Tua island. Latitude/longitude: 1° 38′ N, 124° 43′ E.

(4) *Name of fisherman*: Om Lameh Sonatham, 56 years of age, owns and is in charge of the shark gill-net which captured the fish, and he and his son Samuel brought the fish to the first author's house on the morning of 30 July 1998.

(5) *Distance from shore at capture*: Approximately 250–400 m from shore. The shallow (1–7 m) reef flat here is approximately 150 m wide, eventually sloping to a 50 m wide shelf at 15–20 m depth. From the edge of this shelf the reef slopes steeply to over 1000 m depth. The shark net is anchored at the edge of the reef flat with a 200 m long rope, and the net itself is approximately 150 m in length.

(6) *Depth of capture*: Approximately 100–150 m depth. As the net itself is 150 m long, and extends downwards along the reef slope, it is difficult to make a more accurate approximation of the depth of capture.

(7) *Bait used*: No bait was used. As mentioned above, this specimen was captured with a deep-set shark gill-net. Details of the net are provided in Erdmann (1999).

(8) *Weight*: 29.2 kg, weighed shortly after death and before freezing.

(9) *Length*: The specimen was 124 cm TL (tip of snout to tip of epicaudal lobe), and 119 cm SL (tip of snout to posterior terminus of notochord). Table 1 summarizes additional body measurements and meristic data recorded during the initial examination of the specimen, with a comparison of these measurements to those reported in McAllister & Smith (1978). Additional fin ray counts not reported by McAllister & Smith (1978) include: dorsal lobe of caudal fin = 24; ventral lobe of caudal fin = 21; and epicaudal lobe = 33 fin rays.

The results of the comparison to McAllister & Smith's (1978) measurements indicate that the allometry of the Sulawesi specimen is very similar to that reported for Comoran *L. chalumnae*. Of the lengths and meristic data measured and proportions calculated, only the proportional lengths of the gular plate and the pectoral fins to the specimen's standard length and the number of fin rays in the left pectoral fin fell outside the reported ranges of McAllister & Smith (1978) for *L. chalumnae*. Furthermore, the log-transformed regression equation of McAllister & Smith (1978, p. 72) for weight of female specimens, using a TL of 124 cm, predicts a weight of 29.5 kg. This prediction is obviously in close accordance with the measured weight of 29.2 kg. Ongoing analyses of mitochondrial DNA sequences of this specimen and comparison to published sequences of Comoran specimens should soon give a clearer indication of the depth of divergence between these two populations of living coelacanths.

(10) *Sex*: Female, with three maturing ovarian eggs, each approximately 3 cm in diameter.

A review of the literature available to us suggests that this is the second smallest-sized female coelacanth known with eggs. The only smaller specimen reported with eggs is CCC no. 4, a female of 1.09 m TL that Millot et al. (1978) report as having a number of immature eggs in the ovary. They did not report the size and number of these eggs.

Unfortunately, the eggs began to deteriorate quickly as the specimen thawed, and subsequent injection with formalin may have been too late to fully preserve them. The eggs showed no appreciable structure beyond a solid sphere of yellow yolk and they were considerably smaller than mature *L. chalumnae* eggs, which typically measure 8.5–9.0 cm in diameter (Millot et al. 1978). Our review of the literature does not reveal a clear distinction between preovulatory oocytes and postovulatory eggs, and their respective sizes. Other reports of female specimens with eggs include: Suyehiro et al. (1982) report a 1.75 m female with around 30 ovarian eggs of maximum diameter 4.5 cm; Millot et al. (1978) report a 1.66 m female with immature eggs up to 2 cm in diameter (specimen C_9, CCC no. 10), and a 1.8 m female with maturing eggs of maximum diameter 7 cm (specimen C_{18}, CCC no. 20); Bruton & Coutouvidis (1991) describe a 1.42 m female with 'maturing eggs' (CCC no. 8) but size was not provided; Bruton (1993) reports 59 vitellogenic, 'chicken egg-sized' eggs from a 1.68 m female (CCC no. 154); and Heemstra & Greenwood (1992) mention a 1.64 m female with at least 65 ovarian oocytes, ranging in size from 3–15 mm in diameter (CCC no. 159).

The literature is not clear on the determination of 'maturity' in female coelacanths; the description of the 1.42 m specimen CCC no. 8 as an 'immature female with maturing eggs' (Bruton & Coutouvidis 1991) suggests that presence of ovarian eggs does not indicate maturity. Interestingly, Bruton & Armstrong (1991) predict maturity of *L. chalumnae* at approximately 1.25 m TL, very close to the size of the present specimen. A more detailed examination of the eggs and reproductive tract of the Sulawesi specimen is clearly warranted.

Table 1. Morphological measurements and meristic data recorded from specimen CCC no. 175. Morphological features are as defined in McAllister & Smith (1978). Lengths are reported to the nearest 5 mm, with the percentage below indicating proportional length of the feature compared to the standard length of the specimen. Reported ranges are only for those specimens above 100 cm SL reported by McAllister & Smith (1978), which ranged from 106.3–162.3 cm SL.

Morphological feature	Length	Reported range	Number of fin rays	Reported range
Head length (to posterior of opercular flap)	33 cm 27.7%	30.7–48.5 cm 27–33%		
Head length (to posterior of bony operculum)	26 cm 21.8%	22.8–39.0 cm 21–26%		
Snout length	8 cm 6.7%	4.3–12.6 cm 4–9%		
Upper jaw length	13 cm 10.9%	9.7–18.8 cm 9–13%		
Lower jaw length	24 cm 20.2%	25.3–34.5 cm 19–22%		
Gular plate length	19.5 cm 16.4%	14.1–24.7 cm 13–16%		
Operculum width	7.5 cm 6.3%	7.4–10.4 cm 6–8%		
Orbital diameter	4 cm 3.4%	3.4–5.6 cm 3–4%		
Body height	25 cm 21%	25.6–43.8 cm 20–30%		
First dorsal fin	18 cm 15.1%	17.6–26.0 cm 13–18%	8	8
Second dorsal fin	22 cm 18.5%	17.8–29.3 cm 13–20%	28	27–31
Pectoral fin	29 cm 24.4%	22.9–33.3 cm 17–23%	30,3	29–32
Pelvic fin	20.5 cm 17.2%	19.2–31.2 cm 16–21%	3,33	29–33
Anal fin	22.5 cm 18.9%	16.2–27.2 cm 15–19%	30	28–30
Lateral line scale count			82	76–82

(11) *Condition on capture*: The fish was still alive when the net was hauled in, and was brought to the home of the first author while alive. The specimen sustained minor injuries from the gill net, including broken fin spines on the first dorsal fin and several lacerations with missing scales on the left side of the body. Additionally, the anal/urogenital opening was inflamed and bleeding.

An attempt to revive the fish by pulling it with a rope behind a wooden speedboat to pass water over its gills was partially successful, as the fish resumed fin movements within several minutes of towing. The first author and his wife were then able to swim with the fish for over an hour while shooting several rolls of film. Fin movements observed were as described by Fricke et al. (1987), including both sculling motions with the second dorsal and anal fins in opposition, and 'underwater flying' using the paired pectoral and pelvic fins as stabilizing 'wings' (Figure 1). We also observed occasional movement of the paired fins in the alternately synchronous fashion described by Fricke et al. (1987), while no substantial motion of the caudal fin was noted. The first dorsal fin tended to remain folded against the body, though it was erected several times when the first author's wife approached it closely (Figure 2).

During this time the fish tended to roll on to its back, and eventually its fin movements became more erratic and the fins limp. At this point, the fish was transported

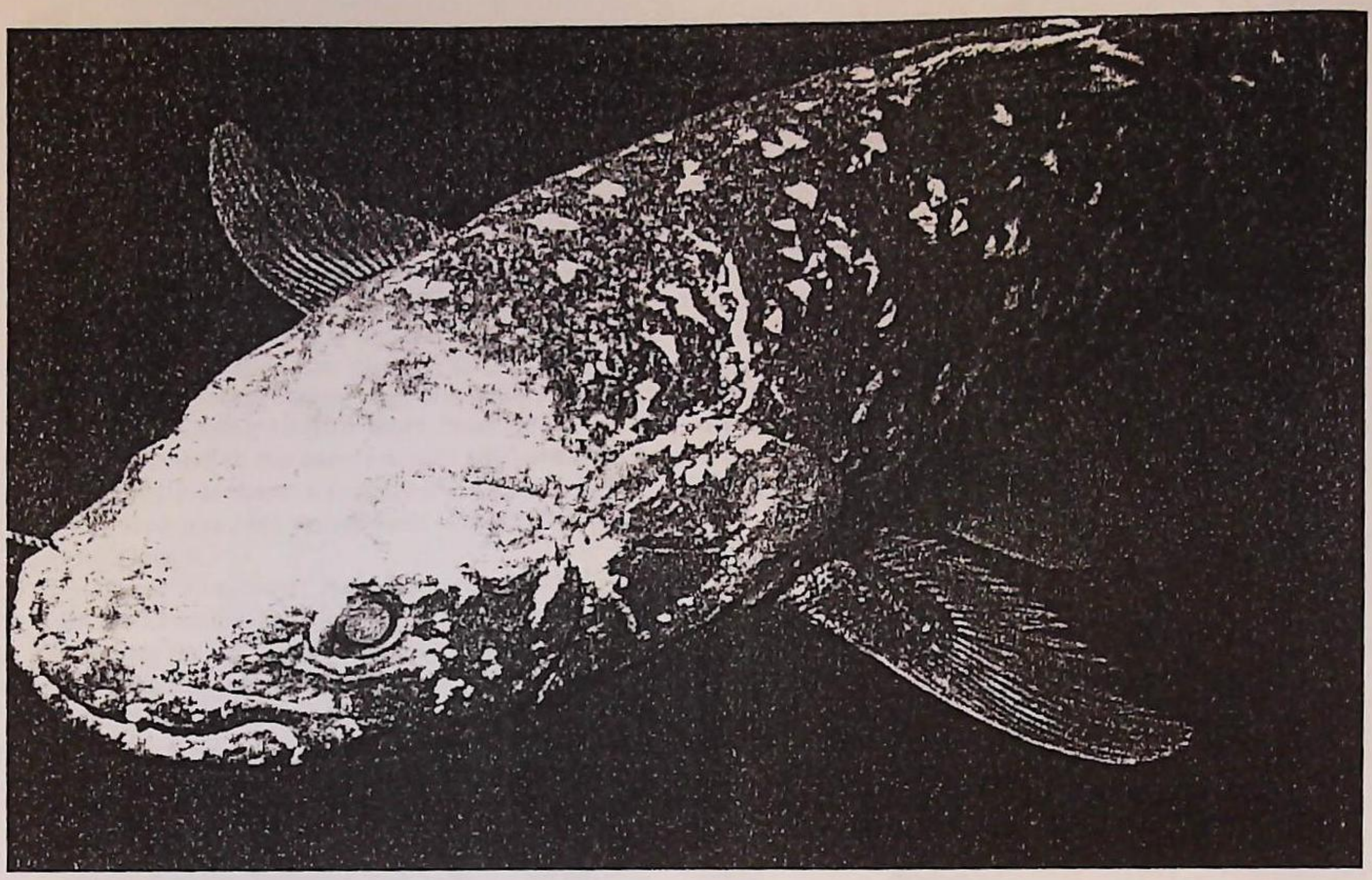

Figure 1. The Sulawesi specimen using its pectoral fins as stabilizing 'wings' while held in a slight current.

via speedboat into the city of Manado, where it was weighed, dissected for tissue samples, and then frozen (Figure 3). The fish survived for almost six hours after being removed from the gill net.

(12) *Method of preservation*: As described above, this specimen was frozen shortly after death. Prior to freezing, a ventral incision was made in the body cavity for the purpose of tissue sample collection. Replicates of the following tissue samples were taken: heart, liver, white muscle (from area of ventral incision), and gill filaments (from the left gill arches). Replicates of each tissue sample were preserved by the following three methods: storage in liquid nitrogen, storage in a regular deep freezer, and storage in 95% ethanol. All scales which were loosened by the incision were also preserved in 95% ethanol.

Two months after the initial freezing, on 28 September 1998, the fish was taken (still frozen) to Jakarta for the purpose of preservation in formalin. Before preservation, several additional tissue samples were taken from the following areas: white muscle from the area of the ventral incision, red muscle and skin from the medial surface of the left pectoral fin, gill filaments from the left gill arches, and additional liver samples. Replicates of these tissues were stored in both 100% ethanol and in DMSO–EDTA–NaCl buffer, as described in Seutin et al. (1991).

Before immersing in 10% formalin, the specimen was injected with full-strength formalin in all fins, organs and throughout the body using a large-bore hypodermic needle fitted to a pressure sprayer. After seven weeks of immersion in 10% formalin, the specimen was rinsed well with water and soaked in water for a full day, then transferred into three successively stronger concentrations of ethanol (35%, 55%, and 70%). The specimen is now stored permanently in 70% ethanol in an airtight glass display case.

(13) *Condition of preserved specimen*: The specimen is generally in excellent condition for morphological investigations. The gill filaments on the left side of the

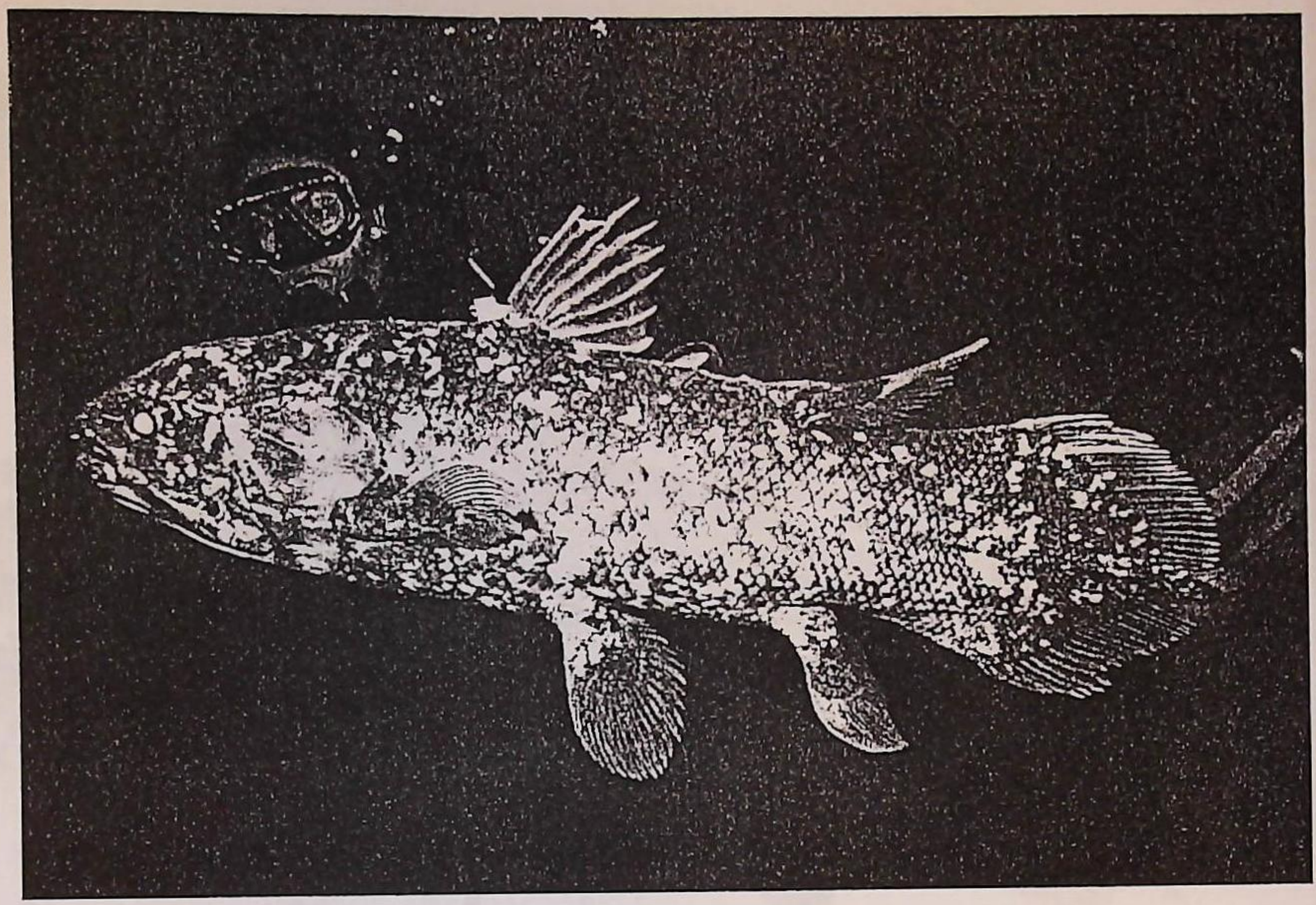

Figure 2. The first author's wife Arnaz swimming next to the specimen in approximately 10 m depth. Note the erect position of the first dorsal fin.

fish, as well as the heart and part of the liver have been mostly removed for tissue samples, but otherwise the specimen is intact. Unfortunately, the eggs began to deteriorate before they were injected with full strength formalin.

(14) *First literature reference*: Erdmann et al. (1998).

(15) *Current holding*: The specimen is currently housed at the Indonesian Institute of Science's Research and Development Center for Biology in Cibinong, Indonesia (near Jakarta), where it will remain permanently. The specimen was accessioned as specimen # MZB10003. There are plans for a public display of a life-size replica of the specimen at the Bogor National Zoological Museum as well.

CITES import and export permits were obtained for the tissue samples, which are now being stored at the University of California, Berkeley. A schedule for distribution of these limited tissue holdings to qualified coelacanth researchers is currently being prepared.

(16) *Additional comments*: As commented upon by Erdmann et al. (1998), the only obvious difference between the current specimen and the descriptions of Comoran *L. chalumnae* is the color. While the Comoran specimens are generally described as steel blue with white pigment blotches (e.g., Balon et al. 1988), the present specimen was distinctly brown in life, though with a slightly bluish cast to the fin edges and operculum. This color difference may be a result of the deteriorating health of the fish when observed; Comoran coelacanths are known to quickly turn brown in coloration after death.

The other color note of interest was the intense pattern of gold flecks covering the dorsal surface of the body of the specimen. This gold flecking appears to be

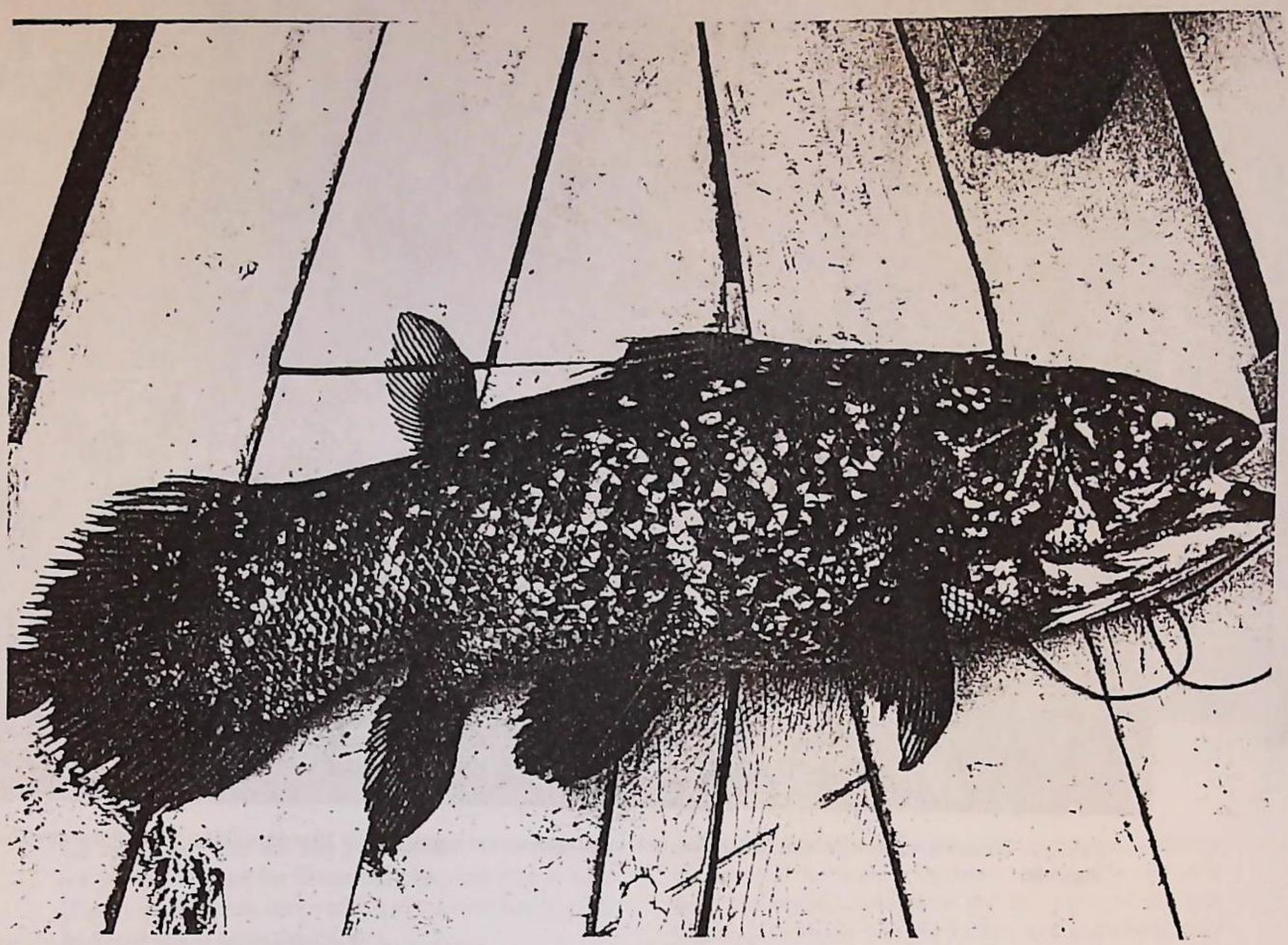

Figure 3. The specimen shortly after death, just prior to freezing.

a result of the prismatic effect of light reflected off the numerous denticles covering the scales of the fish.

Finally, the local name of the fish is 'raja laut', which translates as 'king of the sea' in the Indonesian language. Contrary to the intimation of Forey (1998), however, this name was not previously well-known among the fishing community of north Sulawesi. Rather, this name was actually given to the fish by middlemen fish sellers in an apparent attempt to make the generally inedible coelacanth more marketable to unsuspecting buyers. At the time of the announcement of the discovery of the Sulawesi population, this name was only known to a select few fishermen and fish traders in Manado. Now, thanks to extensive popular media coverage, the name has become a part of the local vernacular.

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for the specimen and tissue, allowed SLJ to fly to Indonesia to lend her expertise in preservation and examination of large fish specimens, and obtained the CITES import permit. The staff of P3B LIPI were most accommodating and helpful in all aspects of the preservation and display process, especially Y. Suhardjono, I. Rachmatika, S. Wirjoatmodjo, R. Hadiaty, Pak Koestoto, and Ibu Lili. Additionally, Pak Subiyanto was invaluable in arranging the CITES permit for tissue export. E. Balon, M. Bruton, K. Cole and V. Springer reviewed the manuscript and offered valuable suggestions. W. Lessard assisted greatly with French translations. Finally, thanks very much to Om Lameh Sonatham and his crew for delivering to the world the first Indonesian coelacanth available for scientific study.

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